GEOGRAPHIC INFORMATION SYSTEMS
A Primer for USAID Managers
Developed for the United States Agency for International Development
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INTRODUCTION

< Computer geographic information systems (GIS) are information systems used for displaying, analyzing and storing geographic information and map data. In its simplest form, a GIS is a series of paper maps overlaid on top of each other, though the term has now has become synonymous with the computer-based systems. This report focuses on the computerized GIS, which is rapidly being incorporated into many aspects of international development.

< Host-country agencies and donor organizations alike now successfully use GIS technology for environmental analyses, monitoring, project tracking, and identification of priority areas for development. Nevertheless, while the technical capabilities of GIS have been proven, its overall role in development work is still being defined.

< GIS holds great potential for development assistance but is not without its problems. In some developing countries and agencies, operational constraints are severe and can adversely affect an otherwise technically sound GIS project. In other cases, misconceptions or ignorance about the technical capabilities of GIS have resulted in wasted money and left goals and expectations unmet.

< This document was written for USAID project managers who are contemplating using GIS, or who already are managing projects with GIS components. Basic GIS concepts are presented, as well as insights from experts into operational considerations necessary for the effective use of GIS in developing countries. Several detailed examples of environmental GIS applications pertinent to USAID's mandate illustrate the utility of GIS. A list of contacts, references and glossary is included for those seeking additional information.

CONTENTS

GIS WHAT IT DOES

GENERAL CAPABILITIES

- GIS can be used to store, display, and analyze geographic information in a spatial or "map-like" configuration in a computer. When linked to a printer or plotter, the GIS can generate top quality maps for reports, field operations or office use. Many systems will perform complex analyses, overlay various layers of maps, incorporate digital remote sensing imagery and global positioning systems data, and conduct modeling operations.

DISPLAY AND OVERLAY ANALYSIS

- The various maps stored in the GIS database can be displayed on the computer screen individually or overlaid on top of each other. By overlaying multiple layers of map information for the same area, the GIS helps the analyst see relationships between different aspects of the environment. Specific map elements (such as polygons or points) can also be displayed independently or in conjunction with other elements. Using the computer mouse (or cursor) map elements on the screen are selected to reveal text or statistics linked to the map elements.

QUERIES

- A corresponding database of thematic and statistical attributes is linked to the map features and can be sorted and classed, then queried to reveal important details not readily seen on the maps. For example, population information relating to administrative units or municipalities might be sorted to show varying population densities among the municipalities. Such variations could then be shown graphically as charts or histograms on the map.

SPATIAL ANALYSIS AND MODELING

- Because GIS map data is geographically registered, statistics such as distances and area calculations can be computed instantly. The GIS can also combine various map layers to generate new outputs, such as land-capability classifications, detections of landscape change over time and other environmental analyses that involve components of space and time.

QUICK UPDATES

- Using a GIS, updates to maps and map attributes can be made directly onto the computerized map. A revised, updated hardcopy version of the map can then be printed quickly.

SUMMARY OF GIS TECHNICAL FUNCTIONS

< GIS capabilities will vary according to software packages. The following summarizes some of the most common functions of the GIS:

- Display graphics and query attributes
- Draw and edit lines
- Enter and modify text or statistical information (attribute data) linked to the map elements
- Overlay various layers of graphics and map data and display simultaneously
- Combine different layers of map data to produce new maps
- Calculate and draw zones of equal distance around map elements (buffering) such as roads, cities,

markets or conservation areas
-Change map projections and "rubber sheet" map data
-Annotate and plot maps
-Import and export various types of computer data
-Display digital satellite data
-Perform spatial analyses (such as distance and area calculations)
-Perform statistical queries of attribute data and sort and rank attributes

GIS USE IN INTERNATIONAL DEVELOPMENT

APPLICATIONS FOR INTERNATIONAL DEVELOPMENT

< GIS has technical applications in many applied sciences. In a recent survey of GIS use in international settings (ENRIC 1994), USAID missions identified the following GIS uses in their host-countries:

- natural resource and environmental
- mapping, monitoring, planning, and assessments
- urban and rural landuse mapping,
- monitoring, and assessments
- flood hazard analysis
- famine vulnerability mapping
- transportation, and utilities mapping and planning
- health care planning
- educational development
- project monitoring, planning, evaluation, and management
- topographic and cadastral mapping.

TIPS FOR DEVELOPMENT WORK

- Many agencies in developing countries have shortcomings in information collection, analysis and management. The technical capabilities of GIS make it very attractive as a tool for rectifying such problems. However, if an organization is unable to manage information using conventional techniques, introducing a GIS probably won't solve the problems. Still, a GIS can be effective in such cases, providing its role and limits are well-defined.

- Managers at many levels in developing countries may not understand or appreciate the capabilities of GIS. Some are complete skeptics. Try to educate them and keep them informed of project progress, even though they may not be directly involved in the operation.

- When expatriates are used to staff projects in developing countries, care should be taken to ensure that host-country staff members also acquire the skills to operate the GIS on their own.

SCOPE OF THE GIS OPERATION

< The cost and complexity of GIS operations can be very diverse. The spectrum of GIS setups can be characterized as desktop mapping, project-level or corporate-level. The following describes these operational scenarios (see Appendix A for examples of associated costs and equipment configurations):

- Desktop Mapping - Though not a true GIS, these systems are useful to review map data for general planning purposes, do simple processing (such as map queries and basic statistics) and output maps and graphics for reports or meetings. They run on standard PC's with a minimum of upgrades. Many are user friendly and most useful to the non-GIS professional who routinely needs to consult geographic information or map data.

- Project-level GIS - The project-level GIS is a true GIS with complete functionality, it usually involves a small number of users and is focused on trying to "get an answer" to a specific problem. It usually is not so concerned with issues such as standards and inter-operability between different parties. Data sets frequently have a short life in terms of their usefulness. Such a system would typically be PC based. Requirements for inputs and outputs are determined according to the need to answer the specific question that justified the acquisition of the GIS.

- Corporate-level GIS - The corporate-level GIS usually serves multiple parties or an unknown number of users with diverse needs and generates data sets with a long life expectancy. Common hardware for these operations include single workstations or multiple workstations. Input and output formats, procedures and methodologies are frequently standardized and documented to assure compatibility among the various users. These characteristics make such a system complex. Consequently, it requires extensive front-end planning and consensus-building among the potential users in order to determine their goals and needs for information and to define the appropriate system, data and personnel requirements necessary to achieve the goals and generate the information.

ASSESSING THE NEED FOR A GIS

THE GIS REQUIREMENT STUDY - THE FIRST STEP

< The GIS requirement study, or needs analysis, establishes if a GIS is justified and how it can be used to help meet project objectives. This study sets the stage for project implementation by identifying:

- GIS applications required to meet project objectives
- GIS functions required to process the applications
- input data required to drive an application
- output requirements (such as map formats) to show application results.

Once determined, these requirements serve to identify appropriate computer hardware and GIS software that would be needed. A requirement study should be fully documented. This documentation is the basis for the development of an implementation plan.

ROLE OF THE REQUIREMENT STUDY IN A TYPICAL GIS PROJECT

(FLOW DIAGRAM NOT AVAILABLE)

DEFINING OBJECTIVES AND REQUIREMENTS

THE OBJECTIVES STATEMENT

< Objectives for the GIS are usually defined during a GIS requirement study. A clear definition of objectives helps to aim the project in the right direction and keep it on track throughout its tenure. All GIS work should ultimately address the stated objectives within the context of institutional and operational considerations. A project objectives statement helps to identify how the GIS technology can best be applied to meet overall goals.

Components of the project objectives statement are:

who the project serves
who is performing the work and under
what authority
the tenure of the project
justification of the project
the major and minor goals of the project
cooperating agencies and other
organizations
the financial value of the project

PERFORMING A REQUIREMENT STUDY IN A HOST COUNTRY

- For complex (corporate-level) projects, the requirement study is typically conducted by an interdisciplinary team of GIS and resource specialists in cooperation with host-country agency personnel. Such a study can take weeks or months to complete. Obtain host-country agency support early on so that the necessary staff will be dedicated to the task.

- Investigate and document constraints that may impact project execution during the requirement study. Difficulties sometimes arise in obtaining data needed for inputs and acquiring and maintaining computer hardware and software. Investigate the limitations of the executing agency to perform the required work.

- Many consulting firms have checklists of specific criteria for the requirement study. Choose a firm with experience in the country and disciplines required, as well as competence in GIS technology.

THE GIS IMPLEMENTATION PLAN

< The development of the GIS implementation plan follows the requirement study, spelling out specific details necessary for execution of a GIS. Ideally, the implementation plan is a comprehensive document, though it may also be in the form of several action plans for the specific needs of the project. Generally, the implementation plan includes:

- requirement study information (including objectives, applications, input data requirements, output formats and recommendations for the software and hardware)
- staffing plans (identifies personnel needs, including new hires)
- organizational needs
- training needs
- budget

- plan for system acquisition, installation and debugging (including bidding processes and bid evaluations if appropriate)
- logistics and timing of activities

DEVELOPING GIS APPLICATIONS TO MEET OBJECTIVES

APPLICATIONS DEVELOPMENT

< Once project objectives have been defined, GIS applications can be identified that help meet goals. Initially, applications that can be addressed by the GIS within the constraints of the project are identified. Later on, during project implementation, the need for addition-al applications will become evident also.

(A GIS application is how the technology is applied to meet an objective. An application could be a map, derivative model, document, statistical summary or an analysis of data contained in the data base. Several examples of GIS applications can be found in Appendix B.)

DEVELOPING APPLICATIONS IN INTERNATIONAL SETTINGS

- Encourage GIS specialists to work hand-in-hand with the resource scientists during application development. It's a good time to start the working relationship between the two groups if it doesn't already exist.

-Anticipate frequent reversals and dead ends during applications development, as some applications prove too complex or needed input data are missing.

- Work out possible applications on paper first. As the GIS team begins working through the details of the desired applications, the feasibility of actual implementation will become clearer.

GUIDING APPLICATIONS DEVELOPMENT DURING THE REQUIREMENT STUDY

< A set of standardized applications development forms can help guide the development process. Have blank forms and a filled in example ready to go at the start of the requirement study.

Applications development forms should generally include:
- name, scale and archiving code for the application
- who the application is for and when it is required
- goal of the application
- list of data inputs necessary for driving the application
- a summary of GIS functions and processes required by the application
- the type of output (such as a map, model, document, analysis or other)
- software type and version to be used
- a mock-up of the map product and corresponding legend
- all GIS commands and processing steps required for the application

Type up the applications development forms and include them as a part of the requirement study documentation.

DEVELOPING THE DATA BASE TO DRIVE APPLICATIONS

DATA BASE DEVELOPMENT

< A GIS needs input data in order to process applications and produce outputs. Input data requirements are identified during the requirement study, prior to data base development.

Data base development commonly takes up to 80% of project time and resources. A large amount of this time is spent on data entry and digitizing, which produces computer compatible versions of paper maps and other information. Additional time and resources are needed to generate source material for inputs that don't already exist.

Input data may come from
- maps
- tables
- texts
- remote sensing information
- tabular data bases
- digitized maps
- other digital spatial data

Accuracy and quality control standards are needed for all data inputs. Information on data can include
- intended users and uses
- where data was obtained and who to contact for the data
- original scale and scale changes
- date generated
- accuracy information

- description of data and how it was collected
- type of information source (map, satellite image, etc)
- type of data (point, line or polygon)
- description of attribute data and values
- geographic location and information
- transformation processes
- computer format and media

Keep paper records of all project data in a data dictionary.
A second meta-data base is used to keep track of information in the data base.

DATA CONSIDERATIONS IN DEVELOPING COUNTRIES

- High-quality source information is frequently difficult to locate and obtain in a developing country. Local users groups can sometimes provide help on what data are available and where to find it.

- Consider whether high-accuracy inputs are really a concern for each application. Generalized data works fine for some applications and is usually more available in developing countries.

- Once data base inputs have been identified during the requirement study, check out the status of each required input. Make sure the input data exists and can be acquired for the project. Investigate the format of the data to make sure it can be made compatible with the project GIS. Include funds for purchases of data in the budget.

- Data base development typically requires digitizing numerous maps (an intensive activity with high burnout). Consider contracting out digitizing, so the GIS project staff can dedicate themselves to processing the applications and don't lose interest in the work. Apply quality control standards to all contract work.

- Satellite imagery can be a good information source where data are lacking and is particularly useful in developing countries. GPS data can also be useful for some applications, especially when knowing point locations, such as geographic coordinates of new villages, or specific observation sites is important.

MANAGING THE GIS DATA BASE

GENERAL CONSIDERATIONS

< The ability of a GIS to store large amounts of map data for future use is one of its outstanding capabilities. Yet very often needed files cannot be located in the data base and the content and accuracy of GIS data files is essentially unknown. Consequently, the great investment in data entry and digitizing is lost and work has to be repeated. This not only affects individual projects but slows the development of data sets that might be needed to fill gaps required for developing a regional or national perspective on an issue.

The GIS data base should be well structured and organized in order to permit the location, retrieval and use of needed information. This requires the archiving of GIS data in a logical and systematic fashion and the development of thorough support documentation, such as the data dictionary, that accurately describes the contents and structure of the data base. A data base manager should be appointed to screen and track all information to be stored there. Backup copies of the data base should be stored off-site to protect it against fires, leaky roofs, computer problems and theft.

< Filing structures. The GIS data should be structured within a hierarchical series of subdirectories in the computer, which contain the actual GIS files.   The naming conventions of the subdirectories should help the user to identify the information stored there.   Hierarchical data base structures achieve this by segregating information by
- the scale of the information
- its geographical location and extent
- the thematic content of the data

Scale. The scale is sometimes used as the first subdivision (and subdirectory) for a GIS filing structure. Segregating information by scale alerts the user immediately to this major limitation of the data's utility. (Using the scale as the first subdivision also sets the stage for the second subdivision of geographic area, since the structuring of geographic areas are frequently made according to mapsheet units for a map series of a particular scale.)

Geographic area. Dividing the project area into smaller geographic units for storage and use within the GIS is known as "tiling". Each "tile" for a project area would form a separate subdirectory. A useful and practical tiling structure for a geographic area can be based on the limits of an existing map series. Tiles for the GIS files should have unique names and codes that relate them back to the corresponding map. (This "tiling structure" enhances the utility of the GIS map outputs, since they can be readily overlaid onto the existing map.)

Thematic content. For more complex data bases it may be necessary to further segregate the information according to its thematic content. This places such information as roads, hydrology, landcover and others into separate subdirectories and eases the location and retrieval of required files.

< File names. Names for the actual GIS files must also be unique and should ideally reflect
- the scale of the information
- its geographical location and extent
- the thematic content of the data
- a representative date for the thematic information

In order to capture all of the required information in a single file name, abbreviations are frequently needed. Make the abbreviations logical and uniform for all names of all files. Use the same abbreviations to name the file in the meta data base and data dictionary. See the previous section on data base development for hints on information to be included in the data dictionary. Include diagrams of the data base structure and keep copies in the data dictionary also.

REMOTE SENSING AND GIS
TYPES AND USES

< Remote sensing information is information obtained from aircraft or spacecraft, usually in the form of air photos, radar, video or satellite images. Remote sensing information can provide a data source for the analysis of
- land-use
- forest resources
- agriculture
- coastal resources
- geology
- environmental conditions
- water resources
- urban studies

There are two basic formats for remote sensing information, digital (computerized) and hardcopy. Data in both formats can be obtained by the general public, though it takes special skills and training to interpret the hardcopy photos and images, as well as additional expertise and equipment to conduct the computer processing required to analyze the digital data.

ADVANTAGES AND DISADVANTAGES
< The benefits of using satellite imagery with a GIS in developing countries are

- frequently the only reliable data source for isolated areas
- available for most parts of the world
- acquisition is relatively simple via US Government agencies and contractors
- data comes in a standard format so, you know what you're going to get (sample size, resolution, frequencies sampled, angle and altitude of sampling are normally uniform)
- data are digital and compatible for direct input into a computer system (though frequently requires an image processing step before it will work with a GIS)
- historical archives are available and sampling parameters are known (this is critical for making time-series analyses)
- data can be transformed into geographic projections to "fit" other layers of GIS data
- provides a "synoptic" look of an area, useful for identifying major uses
- can be used for a variety of applications (depending on which sensor is chosen), including forestry and land-cover inventories, environmental analyses, geological studies, marine and coastal studies and urban studies
- USAID can obtain Landsat Satellite data at reduced costs for some areas

< Some of the drawbacks to using satellite imagery are cloud cover can obscure the project area rendering the imagery useless (except radar imagery) costs can be high obtaining low-cloud cover imagery for the right dates can be difficult for tropical areas many people don't know how to use it seasonal changes in vegetation and light can alter the phenology or "look" of the imagery additional hardware and software may be necessary to take full advantage of the imagery its capabilities have been overestimated in the past, confusing the issue of its appropriateness for some applications

SELECTING THE REMOTE SENSING DATA SOURCE

< The type of remote sensing information selected for a project will greatly depend on the following:

- spectral characteristics of the phenomenon to be observed

Remote sensing instruments have various sensors to collect data from distinct spectral ranges or wavelengths. Since different types of materials (plants, water, soil, etc.) reflect energy differently, the nature of the reflectance can be used as an aide for interpreting remote sensing information. Depending on the application and the characteristics of the phenomena to be studied, information from the visible, infrared, thermal infrared or radar wavelengths may be required.

- size of the phenomena to be studied or observed

The minimum size of an object that can be observed will vary according to the spatial resolution or "pixel size" of the instrument used.

- size of the study area

Different types of remote sensing data have different swaths or "footprints" and cover varying expanses of the earth's surface for each image, air photo or sampling unit. Many times an application will require several images or photos to provide complete coverage for the project area.

- required dates of the information

Different types of imagery are available for various dates according to their launch date and repeat cycle (satellites) or date of the overflight (airplanes). Having the right date is critical for time-series analyses and for ensuring that GIS applications reflect the conditions for the appropriate date.

- location of the project area

Some satellite images have a restricted range due to the absence of ground receiving stations and other downlink restrictions. Even though the satellite passes overhead it may not have its sensors turned on or be transmitting data to the ground station.

- cloud cover

Clouds can partially or completely obscure the project area. This is especially true for the humid tropics. Imagery should be inspected visually prior to purchase to verify cloud conditions and potential problems.

- phenology

Seasonal changes in vegetation, light and moisture conditions can alter the "look" or phenology of the imagery, and can either enhance or diminish the utility of the imagery. This is especially evident in temperate zones, where seasonal greenup and loss of leaves in deciduous vegetation occurs.

- cost

Costs per digital image (raw data) are currently about $100 for AVHRR data, $200 for MSS data, $2600 for Spot XS or Spot P Data, $1650 for ERS-1 data and $4995 for TM data. These areb basic costs, which do not include hardcopy production, geographic registration to a map base, interpretations and other processing required to make the imagery useful for an application. Variations in these costs can be found and discounts are available for some of the older data. (Most of the firms indicated that these prices would be changing soon.)

Frequently tradeoffs have to be made between what's ideal technically, what's affordable for a particular project and the availability of specific imagery for a particular locale. A remote sensing specialist should help you define the details of your purchase, as well as the necessary image processing to be conducted.

CHARACTERISTICS OF COMMON REMOTE SENSING INSTRUMENTS

SENSOR

Pixel Size

Pixel = smallest picture element

Coverage

Display and Analysis Scales

Inception

Repeat Cycle

Spectral Resolution

Advanced Very High
Resolution Radiometer
(AVHRR)

1.1 km x 1.1 km

2700 km x 2700 km

1:2,500,000 to 1:500,000

1979

1 day

visible
near infrared

thermal infrared

Landsat Multispectral
Scanner (MSS)
56.5 m x 79 m
185 km x 185 km
1:1,000,000 to 1:100,000
1972
16 days
visible
near infrared

Landsat Thematic Mapper
(TM)
28.5 m x 28.5 m
120 m x 120 m
185 km x 185 km
185 km x 185 km
1:500,000 to 1:50,000
1:500,000 to 1:150,000
1982
16 days
visible
near infrared
short-wave infrared

Indian Remote Sensing
Satellite LISS-1
72.5 m x 72.5 m
148 km x 174 km
1:1,000,000 to 1:100,000
1988
22 days
visible
near infrared

Indian Remote Sensing
Satellite LISS-2
36.25 m x 36.25 m

145 km x 161 km
1:500,000 to 1:75,000
1988
22 days
visible
near infrared

ERS-1 Synthetic Aperture
Radar (SAR)
33 m x 33 m
100 km x 100 km
1:500,000 to 1:50,000
1992
35 days
microwave

SPOT Multispectral
Scanner (XS)
20 m x 20 m
60 km x 60 km
1:250,000 to 1:35,000
1986
26 days
visible
near infrared

SPOT Panchromatic (Pan)
10 m x 10 m
60 km x 60 km
1:100,000 to 1:20,000
1986
26 days
visible

Aerial Photography
variable
variable
less than or = to 1:1,000

n/a
n/a
visible
near infrared

Aerial Videography
variable
variable
variable
n/a
n/a
visible
near infrared

Side-Looking Airborne
Radar (SLAR) - variable - variable - variable - n/a - n/a - microwave

GIS OUTPUTS - DISPLAYING RESULTS

MAP PRODUCTS

< Though the GIS can produce tables and statistical printouts of data, the most common GIS outputs will probably be maps of some type. The land use/land cover map of Banjul, Senegal (opposite page) is an example of a typical GIS output. Depending on the application, the map may be highly technical or very general. Whatever the case, the map should be self-descriptive, informative and easy to interpret by the audience it is aimed at.

Information presented on technical map products generated by a GIS should generally include
- title of map
- description of theme
- scale information and scalebar
- geographic projection, spheroid, north arrow and location diagram
- legend
- methodology, software and inputs used to
- generate the map
- archiving code and date generated
- geographic grid and tic marks
- accuracy statement
- institution responsible & participating entities
- disclaimer

(Simpler map products are appropriate for less technical applications and don't require the level of detail specified above.)

MAPS AND THE DEVELOPMENT PROCESS

- Getting to the point of producing a single output(map or table) to meet project objectives can take months or even a year or longer. Prior to generating an output a requirement study is performed, equipment is acquired, installed and debugged, data bases built, and the staff trained.

- Include some simple interim outputs that look nice and can be produced quickly after startup. Put a copy on the wall and circulate additional prints. This demonstrates the utility of the system, helps the moral of the staff and keeps agency officials interested in the project.

- Once an acceptable output has been generated that meets the project needs, move on to the next objective. Know when to quit. Minute enhancements in details may not be necessary or justified in terms of costs or time spent.

- Many organizations in developing countries already have standards for maps include these in the map format when appropriate.

STATEMENT OF WORK (SOW) FOR GIS DELIVERABLES

< Though GIS deliverables will vary greatly according to need, a typical set of deliverables might include

- four precision-scaled hardcopies with specified map features as outlined above (two paper and two of stable base material ,e.g. mylar, suitable for blueline printing).
- computer compatible versions of relevant GIS products generated (in a format and media - compatible with your system, if you have one).
- evaluation of results (such as how much deforestation or list of villages in danger of flooding, etc.).

- thorough explanation of methodology used including inputs (dates, original scales, types and accuracies), software/hardware used and GIS processing steps.
- basic information on the paper and digital deliverables (see the section on data inputs and the data dictionary for the type of information required for a meta-data base).

GIS AND PERSONNEL REQUIREMENTS

TRAINING AND STAFFING

< Training and staffing issues will vary widely depending on the scope and complexity of the GIS operation. The more complicated the task and the hardware and software, the more training will be required. However, in general technical training should be sufficient so that personnel can

- operate all computer hardware and
- necessary software
- monitor system and perform routine
- maintenance
- design and build spatial and attribute data bases
- process applications
- create required outputs

Additional training should be conducted for

- systems administration
- program management
- project management
- applications development for specific disciplines

TRAINING WITH HOST-COUNTRY AGENCIES

- Staff turnovers tend to be high on GIS projects in developing countries. Once personnel become trained in GIS by government agencies they often seek better paying jobs with private businesses.

- Plan and budget for retraining throughout the lifetime of the project to account for turnovers and to advance the skills of other staff members.

- Identifying and recruiting qualified host-country staff for projects is frequently difficult in developing countries. Competent local trainers are often hard to find also.

- Combining training with project implementation is usually not effective. Because there is much repetitive work during project execution, staff members tend to get limited experience in the entire scope of GIS activities necessary for a comprehensive understanding of the technology.

GIS AND COMPUTERS

COMPUTER HARDWARE AND SOFTWARE

< One important result of the requirement study is the configuration of the computer hardware and GIS software needed to process the applications.

Dozens of software options are now available for GIS and recent advances in personal computers and mini-computers have made powerful platforms affordable to small operations. Appendix A contains three examples of computer configurations appropriate for different GIS setups.

Time the date for system selection and acquisition to maximize advances in software and hardware. Check out the software maintenance agreement to see if it includes upgrades.

COMPUTERS IN DEVELOPING COUNTRIES

- Investigate what hardware and software vendors are represented in your country and the level of service they can provide for installation, training and maintenance. Check the local vendor's record with some of their past clients to make sure they're reliable.

- In places where hardware and software services are lacking, set up an efficient supply route to your project. If you have to check materials through customs, be prepared for delays and import duties.

- "Let the buyer beware" stands for computers and GIS software in all countries. A computer and GIS specialist should help in selecting the right hardware and software, not just the vendor. Don't get stuck with the wrong system or the wrong vendor, they're recipes for big trouble with your operation.

RESOURCES FOR USAID ON GIS

AFRICA
Mr. Jake Brunner (WRI/USAID/NRICG)
World Resources Institute
1709 New York Ave., NW
Washington, D.C. 20006

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E Mail: jbrunner@wri.org

AFRICA
Mr. Mark Buccowich
USDA Forest Service (International Forestry Office)
P.O. Box 96538
Washington, DC 20090-6538

Fax: (202) 273-4750 or -4748
E Mail: fswa/s=j.buccowich/ou=w01@mhs.attmail.com

LATIN AMERICA & CARIBBEAN
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ASIA & N.I.S.
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APPENDIX A:

GIS COMPUTER CONFIGURATIONS AND COSTS

EXAMPLES OF VARIOUS GIS COMPUTER
CONFIGURATIONS AND ILLUSTRATIVE COSTS

DESKTOP MAPPING COMPUTER CONFIGURATION
COMPUTER = $3,500
-80486 processor
-math coprocessor
-33 mhz (minimum clock speed)
-8 mb RAM
-500 mb hard drive
-mouse
-CD ROM
-14" color monitor
-1.44 mb floppy drive
-graphics card

PERIPHERALS = $3,750
-mid-level laser printer
-UPS
-tape backup unit
-color printer

SOFTWARE =- $2,200
-MS DOS 6.0 and windows
-spreadsheet software (eg. Excel, Lotus or Quattro Pro)
-utilities software (eg. PC tools or Norton Utilities)
-Desktop mapping software (eg. Arcview or Mapinfo)

TOTAL ESTIMATED COST FOR DESKTOP MAPPING SYSTEM = $9,450
PROJECT-LEVEL PC-BASED GIS COMPUTER CONFIGURATION
COMPUTER = $5,000
-Pentium processor
-math coprocessor
-66 mhz clock speed (minimum)
-16 mb RAM
-750 mb hard drive (SCSI)
-bus mouse
-14" color monitor
-Super VGA graphics card

-Accelerator board
-1.44 mb floppy drive
-CD ROM

PERIPHERALS = $19,250
-mid-level laser printer
-UPS
-8 mm tape backup unit
-Color printer
-24" x 36" digitizing table
-36" pen plotter

SOFTWARE = $3,200
-MS DOS 6.0 and windows
-spreadsheet software (eg. Excel, Lotus or Quattro Pro)
-utilities software (eg. PC tools or Norton Utilities)
-Completely functional PC-based GIS software (eg. ArcCAD, pc ARC/INFO, ReGIS, etc.)

TOTAL ESTIMATED COST FOR PC-BASED PROJECT-LEVEL GIS = $27,450
CORPORATE-LEVEL WORKSTATION GIS COMPUTER CONFIGURATION
COMPUTER = $25,000
-UNIX-based workstation
-8 bit display
-8 bit controller and software
-19" color monitor
-128 mb RAM
-5 gigabyte hard drive
-mouse
-Ethernet controller

PERIPHERALS = $24,000
-laser printer
-UPS
-8 mm tape backup
-CD ROM unit
-color printer
-24" x 36" digitizing tablet
-36" pen plotter

SOFTWARE = $29,000
-UNIX operating system with Openlook or Motif
-Terminal emulation software
-PC emulation software

-Full-featured workstation GIS software (eg. ARC/INFO)

TOTAL ESTIMATED COST FOR SINGLE STATION CORPORATE-LEVEL GIS = $78,000

APPENDIX B:

EXAMPLES OF GIS APPLICATIONS

GIS APPLICATIONS FOR INTERNATIONAL DEVELOPMENT

< The following pages contain several generalized descriptions of GIS applications which are relevant to USAID's mandate. The majority of these applications are based on work conducted by contributors to this document. Additional applications were developed by GIS and resource specialists for demonstrative purposes and are based on actual work that could have benefitted from using GIS.

The descriptions of the GIS examples are divided into seven principal considerations, as follows:

<Objectives

The objective is the conceptual focus for the application. All GIS work should ultimately address the project or program objectives. While this seems obvious, many problems in the application of GIS technology stem from a lack of clear conceptual objectives.

<Application

The application describes how the GIS technology will be applied to address the objectives. Knowing the limits of the GIS are needed in order to appropriately develop an application that will meet the project objectives, as well as to determine when GIS use isn't appropriate or practical.

<Scale

The scale refers to the relative size of the geographic information that will be used in the GIS in relationship to the actual features this information represents on the earth. Ideally, scales are selected according to the technical requirements of the application. However, often inputs at the most appropriate scales simply don't exist in developing countries.

Scales used in the examples are based on "commonplace" scenarios for developing countries, where scales are determined according to the dimensions of the phenomena to be analyzed, as well as the availability of inputs at appropriate scales.

<Input Data

Input data is the data needed to drive the applications. Remember that the final output and analysis is only as good as the inputs utilized. Inputs in the examples illustrate input data that would probably be available in many developing countries. Emphasis was given to include remote sensing data since it is commercially available for most places in the world.

<GIS Processing

The GIS processing section gives a generalized description of the major processing steps for each application. It's not a cookbook for the application. A breakdown of all the details needed for GIS processing of each application would comprise many pages of text and include actual commands. It's recommended that such details be written up before you embark on your application though if you can't write the processing steps on paper, you won't be able to do it at the computer.

<Output
The output refers to the end product that will be generated by the GIS analysis. Usually, this will be a map of some sort with accompanying text and statistics. Final outputs will vary widely according to the specific needs of the application. Tips are provided regarding useful elements that might be included in the outputs.

<Expertise Required
For complex applications, a project team of several disciplinary specialists may be required to conduct the analyses and generate the outputs. For simpler tasks, a single person with a broad background in GIS use and subject knowledge in the problem area can be sufficient. In general, most applications will require

- knowledge of GIS principals and specific software packages
- computer proficiency
- knowledge of cartographic principals
- experience using GIS in an operational setting
- knowledge of the technical discipline and nature of the problem that the GIS will be used to address

EXAMPLES of GIS APPLICATIONS
USAID FIELD ACTIVITY-TRACKING
APPLICATION SCENARIO/APPLICATION TIPS

<OBJECTIVE

Provide information on the location and description of USAID field activities

TIP-

Maps showing the locations of USAID activities in the field can help visualize and coordinate multiple activities and identify gaps or opportunities in the development process.

<APPLICATION

Country-wide spatial and thematic data base of USAID projects

TIP-

A user-friendly interface would allow novice computer users to geo-reference new activities, access project information, and view or print maps or text.

<SCALE

11,000,000 or larger, according to availability of digitized base maps

TIP-

The Digital Chart of the World base map at a scale of 1:1,000,000 is available for GIS applications and is appropriate for all but the smallest countries. Smaller
countries will usually require scales of 1:500,000 or 1:250,000 or larger base maps.

<INPUT DATA REQUIRED

a) point locations or boundaries of USAID sponsored field activities, b) digital base map
c) standard descriptions of field activities

TIP-

Point locations for project areas can be derived by correlating project sites to geographic locations using maps and/or GPS units. A simple requirement to provide georeferencing for all USAID project sites by contractors and NGO's receiving USAID funds would greatly facilitate this application.

<GIS PROCESSING

a) build spatial data base of geographic points or boundaries of field activities and the relational data base of activity descriptions, b) digitize or access national base map (e.g. DCW -- see tips), c) join point data base with map data, d) build a user friendly menu to facilitate in-putting of and retrieval of information.

TIP-

Complementary datasets for points or bounded areas can hold data from indicator monitoring, as well as descriptions of project activities.

<OUTPUT

user-friendly data base interface, allowing a) display and analysis of location-specific USAID project activity, b) display of related information such as population distribution or forest cover,

landuse, or soil erosion, and c) printed reports and maps
TIP-
While the final product in this case is a computer data base, the user should be able to generate different types of hardcopy maps and tables or texts for reporting on various USAID activities in the country.

<EXPERTISE REQUIRED
a) data base programming, b) GIS and c) knowledge of USAID project activities and location coordinates of project sites
TIP-

BIODIVERSITY CONSERVATION PLANNING
APPLICATION SCENARIO/APPLICATION TIPS

<OBJECTIVE

Identify priority areas for USAID investments in biodiversity conservation

TIP-

The Biodiversity Support Program in cooperation with leading NGO conservation groups developed this application for Tropical America.

<APPLICATION

Biodiversity conservation priority maps for the American Tropics.

TIP-

This application was executed to assist USAID missions in the LAC region to set priorities for their investments in biodiversity habitat conservation.

<SCALE

Various Maps at 1:10,000,000; 1:5,000,000 and 1:1,000,000

TIP-

Maps were designed to cover many national regions, so scales were small.

<INPUT DATA REQUIRED

a) various biogeographical maps, b) various maps of physical conditions (soils, elevations, etc.), c) various plant and animal species distribution maps, d) infrastructure maps (roads, urban areas, etc.), e) various maps of vegetation, f) maps of parks and protected areas.

TIP-

Input data were collected from various sources at various scales.

<GIS PROCESSING

a) inputs were overlayed in the GIS to produce outputs suitable for further review by panel of experts, b) expert opinion was used to classify and rank areas according to multiple characteristics shown GIS map overlays.

TIP-

The GIS overlays were used as an instrument for displaying multiple layers of information simultaneously. In this way, the expert panel was able to see important relationships and classify and rank priorities for biodiversity conservation at a small scale.

<OUTPUT

Maps showing geographic priorities for investing in biodiversity conservation in Latin America and the Caribbean.

TIP-

14 maps were produced at the indicated scales. These maps showed biological value, threats to biodiversity, conservation status and recommended investment priorities, which were subject to additional review.

<EXPERTISE REQUIRED
a) GIS, b) status of biodiversity for all regions analyzed, c) USAID planning and budgeting criteria
TIP-

MEASURING DEFORESTATION
APPLICATION SCENARIO/APPLICATION TIPS
<OBJECTIVE
Measure deforestation and locate major areas of deforestation in a large region.
TIP-
Monitoring deforestation is an important component of USAID's Natural Resource Management Project in Panama.

<APPLICATION
Forest-cover change detection and quantitative analysis of forest loss.
TIP-
Application relates directly to the objective.

<SCALE
1:500,000 or larger
TIP-
Scales of 1:500,000 to 1:250,000 are frequently used at the regional levels. (Landsat satellite images are frequently analyzed at the 1:250,000 scale.)

<INPUT DATA REQUIRED
a) map of forest cover from time 1; b) map of forest cover from time 2
TIP-
Reliable input data can be difficult to obtain in a developing country. Satellite data may be the only alternative if local sources do not exist. Add plenty of extra time (weeks or months) and additional funds to the task if you have to order input data or conduct the forest inventories yourself. Satellite data can be purchase in digital or hardcopy. If you purchase digital data you'll need the right equipment and personnel to process it.

<GIS PROCESSING
a) digitize input map data and build attribute data bases, b) select forest cover from time 1, select all non-forest landcovers from time 2, c) intersect forest cover from time 1 with all non-forest landcover types in time 2, d) reclassify intersected areas to reflect past forest cover and present land cover, update data base, e) query data base to perform quantitative assessment of forest-cover loss and land-cover change, f) produce scaled map with legend and output to plotter

TIP-
Several days or more processing time would be used for digitizing the input data, building the attribute

data base and making an attractive output map. Actual processing for detection of the change would only take a few hours after inputs are ready.

<OUTPUT
a) scaled paper map with legend showing deforested areas from time 1 to time 2
b) printout of land-cover change statistics quantifying forest loss
TIP-
Highlight deforested areas with color-coding. Place deforestation statistics on the output.

<EXPERTISE REQUIRED
a) GIS, b) remote sensing, c) forestry, d) knowledge of regional and local deforestation problems, e) change-detection techniques
TIP-
Additional expertise in digital image processing techniques is required unless satellite imagery is purchased in hardcopy format.

URBAN STUDIES APPLICATION
APPLICATION SCENARIO/APPLICATION TIPS
<OBJECTIVE
Quantify rate and pattern of urban growth.
TIP-
Measuring urban expansion could be a useful adjunct to planning USAID support for addressing urban environmental problems.

<APPLICATION
Urban change-detection map and study.
TIP-
Urban growth and expansion can be guided or contained so as to minimize risks from natural disasters and reduce environmental impacts of urban landuses.

<SCALE
1:50,000
TIP-
Scales of 1:50,000 are useful for general urban expansion studies. Note the scale is much larger than regional forest change mapping, since the city is a much smaller entity to be analyzed.

<INPUT DATA REQUIRED
a) map of urban & non-urban areas from time 1; b) map of urban & non-urban areas from time 2

TIP-
Sources of accurate spatial information for cities are high resolution satellite data, aerial photography,

airborne videography, existing maps, and ground surveys. Consider satellite data because of the historical archives available. SPOT satellite 10 meter panchromatic (black and white) data are particularly useful for urban expansion studies.

<GIS PROCESSING

a) digitize input map data and build attribute data bases, b) select urban areas from time 2, select all non-urban areas from time 1, c) intersect urban area from time 2 with non-urban areas from time 1, d) reclassify intersected areas to reflect both past non-urban cover (time 1) and present urban cover (time 2) and update data base, e) query data base to perform quantitative assessment of urban expansion and rate of expansion, f) produce scaled map with legend and output to plotter

TIP-

Processing steps for this application and other monitoring applications are similar to the processing outlined previously for mapping deforestation. Nevertheless, the characteristics of the phenomena to be monitored will dictate aspects such as scale, source material for inputs and variations in specific processing steps.

<OUTPUT

a) scaled paper map with legend showing urban areas from time 1 and areas changed to urban in time 2 (indicate previous cover of areas that changed to urban also), b) printout of change statistics quantifying expansion of urban area and loss of other non-urban landcover, c) calculation of rate of urban expansion (hectares per year).

TIP-

Label locational references on the maps such as major roads, parks and important buildings. This will help orient the map user.

<EXPERTISE REQUIRED

a) GIS, b) remote sensing, c) urban planning, d) knowledge of study area, e) change-detection techniques

TIP-

Again, you'll need expertise in digital image processing techniques if you process your own digital satellite data or other remote sensing information.

COMMUNITY RESOURCE MANAGEMENT MAP
APPLICATION SCENARIO/APPLICATION TIPS

<OBJECTIVE
Locate and describe community or indigenous tenure and uses of forests and natural resources. USAID provided funds to NGO's for institutional strengthening among rain forest-dwelling indigenous groups in Central America. Mapping indigenous use of tropical forest lands was part of this effort.

<APPLICATION
Community level map of natural resources patterns and uses.
Tip-
Fishing and hunting areas, grazing commons, water sources and other community resources can also be mapped using this method.

<SCALE
1:50,000 and larger.
TIP-
The 1:50,000 scale was selected because it is the standard for the national map series. Additional maps at 1:6,000 would be useful for the indigenous communities.

<INPUT DATA REQUIRED
a) GPS points for forest use areas, b) information on forest use, c) national map series maps for study area, d) locations of non-indigenous settlements, all roads and drainages.
TIP-
Extensive field work with the participation of community members is required in order to locate and identify the forest-use areas. This application harnesses the combined utility of Global Positioning Systems (GPS) and GIS to overcome the limitations of conventional location-finding techniques, which don't work well or at all in tropical forests.

<GIS PROCESSING
a) digitize relevant features of national map series maps and build attribute data base, b) load GPS point data and convert to GIS format, c) clean GPS data, build attribute data base of forest use for points and build polygons for forest use from point, attribute data and field notes d) overlay forest use polygons onto national map series maps, e) overlay roads, streams and locations of non-indigenous settlements, f) compose maps and output to plotter.
TIP-
Electronic dataloggers for recording point information are available with some GPS units. Data from dataloggers can be transferred directly into the GIS.

<OUTPUT

a) scaled map showing forest areas traditionally used by local indigenous groups, locations of indigenous communities and other settlements, roads and drainages formatted to overlay onto the national map series.
TIP-
Map size and format corresponds to national map series since new thematic maps will be used for official planning. Maps can include indigenous classifications of forest (or other) resources.

<EXPERTISE REQUIRED
a) GIS, b) GPS use and c) knowledge of local areas, d) national mapping standards
TIP-

POLLUTION DETECTION
APPLICATION SCENARIO/APPLICATION TIPS
<OBJECTIVE
Detect sources of thermal pollution in bodies of water near new industrial sites as a first step in an environmental assessment aimed at pinpointing causes of recent declines in fish populations.
TIP-
Assisting developing countries in environmental impact assessments is an important component of USAID's Environmental Planning and Management Project.

<APPLICATION
Thermal pollution detection and monitoring of a lake
TIP-
Sustainable development requires that industrial growth be balanced with ecological concerns.

<SCALE
1:200,000
TIP-
The 1:200,000 scale is compatible with the limits of the 120 meter pixel data of Landsat's thermal satellite channel.

<INPUT DATA REQUIRED
a) map of thermal data for lakes and industrial sites from 10 years ago b) map of thermal data for lakes and current industrial sites from present
TIP-
For mapping changes in thermal activity, input data for this study was obtained from Landsat's thermal-channel satellite data. Point locations of industrial sites can also be obtained from Landsat's other channels.

Satellite data comprise an important historical baseline for monitoring purposes such as this.

<GIS PROCESSING
a) recode TM band 6 thermal data for two dates showing major thermal gradients and covert to GIS polygons, b) build spatial and attribute data bases, c) intersect present and historic thermal datasets to measure changes in thermal gradients, d) overlay points showing historic and current locations of industry, e) calculate changes in thermal activity and number of new industrial sites discharging thermal waste, f) develop map showing changes and output
to plotter
TIP-
Input thermal data for both dates should be grouped and recoded to show major thermal gradients, requiring an image processing step before the data are compatible with the GIS.

Overlay location data for industrial sites to show relationship between pollution and sources. Add names of industries and industry information to the attribute data base for increased utility.

<OUTPUT
a) map showing changes in thermal gradients and old and new industrial pollution sources,
b) statistical analysis of changes in thermal activity Use multiple colors to graphically show changes in thermal activity and thermal gradients. This helps a technical output to become user friendly.

<EXPERTISE REQUIRED
a) GIS, b) advanced image processing, c) wetlands and fisheries biology

FLOOD HAZARD MAPPING
APPLICATION SCENARIO/APPLICATION TIPS
<OBJECTIVE
Locate settlements at risk of flooding at different flood-stage levels
TIP-
Mapping settlements at risk of flooding using GIS was supported by USAID in Bangladesh.

<APPLICATION
Flood hazard map showing settlements at risk Identifying settlements at risk of flooding helps prepare for disaster relief assistance and can provide information relevant for guiding infrastructure development.

<SCALE
1:50,000
TIP-
Scales of 1:50,000 or larger are recommended to identify specific settlements along rivers.

<INPUT DATA REQUIRED
a) topographic map with drainage net, settlements and contour lines b) GPS data of new streamside

settlements c) calculations for flood stages
TIP-
Use existing topographic maps for elevation information and channel locations. Update stream information and population centers with satellite data when available. Use GPS units to locate coordinates of new settlements not present on maps or images.

<GIS PROCESSING
a) Digitize input data and build attribute data bases, b) construct new GIS data layer consisting of GPS locations of new settlements and old settlements, c)select contour lines that demarcate the estimated flood stage of various channels and select settlements, d) create new flood stage polygon, e) intersect settlements with flood stage polygon, and update data base, f) produce scaled map of settlements in flood area and drainage net and output to plotter; list the settlements at risk.
TIP-
Digitizing contours from topographic maps is tedious and time-consuming. Quality control on digitizing is imperative. Some GPS data can be transferred directly from the GPS unit into the GIS.

<OUTPUT
a)Scaled map with legend showing settlements at risk in flood zone and stream drainages, b) printout of names of settlements at risk and assessment of potential flood loss.
TIP-
Roads and airfield locations are critical to disaster relief planning and response operations be sure to include them on the map.

<EXPERTISE REQUIRED
a) GIS, b) watershed management, c) knowledge of local stream and watershed conditions,
d) coordinates of settlements, e) GPS use
TIP-

WATERSHED PROTECTION
APPLICATION SCENARIO/APPLICATION TIPS
<OBJECTIVE
Determine appropriate soil conservation measures for an upland watershed and show locations of recommended conservation treatments on a map of the watershed.
TIP-
USAID has sponsored watershed management projects in Haiti, Costa Rica, Indonesia and elsewhere.

<APPLICATION
Land-capability classification of watershed according to FAO treatment-oriented scheme for hilly watersheds
TIP-

We chose the FAO conservation scheme which contains only two variables (slope and soil depth) and has been used in developing countries.

<SCALE
1:12,500
TIP-
Scales of 1:6,000 to 1:12,500 are recommended for watershed planning. Base maps at such large are not common except around major water projects, where maps have been made for engineering purposes. Use of scales to 1:50,000 are acceptable for large watersheds but are not effective for local planning. Consider making the large-scale base maps yourself
only if you have enough time and resources.

<INPUT DATA REQUIRED
a) watershed map(s) showing soil depths , b) watershed map(s) showing gradients of slopes,
c) drainage net and d) land cover maps compiled through photo-interpretation of recent, large scale (1:30,000 or larger) air photographs.
TIP-
Soil and slope maps are some of the more common thematic maps which may be available. Slope maps can be derived from topographic maps with additional GIS processing, but soil maps entail intensive, long-term field work.

<GIS PROCESSING REQUIRED
a) digitize input map data and build relational data bases, b) reclassify gradients of slopes and soil depth according to FAO classification scheme c) intersect slope data with soil depth data to identify the 12 categories of conservation treatments recommended by the FAO for watershed conservation, d) overlay drainage net, e) produce scaled maps with legend and output to plotter
TIP-
Digitizing map data and building the attribute data base will take up the most time. Soils maps sometimes have complex data bases which require much time and technical skill to construct. Consider building a simple soils data base with as few attributes as possible in order to facilitate the application.

<OUTPUTS
a) scaled paper maps with legends showing type and location of conservation treatments for a hilly watershed and locations of major streams and drainages
TIP-
Multiple mapsheets will probably be required check edge matching. (See annexed table of common problems with GIS data.)

<EXPERTISE REQUIRED
a) GIS, b) watershed management and soil conservation, c) remote sensing
TIP-

APPENDIX C:

COMMON PROBLEMS WITH GIS DATA
COMMON PROBLEMS WITH GIS DATA
(A) PROBLEM
(B) EFFECT ON GIS OUTPUT
(C) EFFECT ON UTILITY OF GIS APPLICATION
(D) ALTERNATIVES

- (A1) Scales of map inputs to be combined for an application are very different (for example, one small-scale map and one large- scale map).
- (B1) Locations of map features on the new features with detailed locations. Consequently, maps will not accurately reflect the spatial distribution of map elements.
- (C1) Generalized data will often crowd the detailed information, so that locations appear closer than they actually are and may incorrectly overlap. Where spatial distribution of elements is important to an application the results are serious, since distances cannot be measured accurately.
Area measurements for generalized data will likely be greater than the detailed information also.
- (D1) Use the map scale for the more generalized data as the scale for the GIS output.
- Acquire new source material at the detailed scale.

- (A2) Errors in map inputs exist in one or more of the data sources.
- (B2) The content and/or spatial distribution of map features of the GIS output will have errors due to errors in the input data.
- (C2) Decisions based on erroneous information will be inherently flawed. (Garbage in = Garbage out)
- (D2) Obtain accuracy information on input data prior to applications processing.
- Develop and apply quality control standards for GIS inputs and outputs.
- Locate and correct errors on inputs on inputs prior to applications processing.

- (A3)Accuracy of map inputs is unknown.
- (B3) GIS product may look good but the map contents and distribution of map features may not reflect the actual situation.
- (C3) Using map data of unknown accuracy for decision-making is risky. Decisions may be flawed leading to problems in meeting overall program goals. Data producers may be liable for damages.
- (D3) Acquire new source material of known accuracy.
- Contact data provider for information on accuracy.
- Contract a disciplinary specialist to produce an accuracy assessment of the source material.

COMMON PROBLEMS WITH GIS DATA
(A) PROBLEM
(B) EFFECT ON GIS OUTPUT
(C) EFFECT ON UTILITY OF GIS APPLICATION

(D) ALTERNATIVES

- (A1) Source data are not compatible with the project GIS software
- (B1) Outputs cannot be generated without input data.
- (C1) Applications will not be produced without input data.
- (D1) Convert data to appro-priate format.
- Contact provider for compatible data set.
- Reenter (digitize) data from hardcopies.

- (A2) Errors induced during construction of spatial and attribute data bases
- (B2) Outputs will contain all errors produced during data entry.
- (C2) Decisions based on erroneous information will be inherently flawed.
- (D2) Develop and implement quality control procedures including check plots for comparison to original hard-copy inputs

- (A3) Different data from adjacent areas must be joined to make a single map of the combined area (tiling)
- (B3) Outputs containing data from adjacent datasets may have edgematching problems resulting in unclosed polygons, broken lines and positional errors in map features due to changes in geographic projections or UTM zones between the areas.
- (C3) Data are unsuitable for application use until all polygons are closed, lines are joined and topology is constructed for the new combined data set. All data contained in a single output must be in the same projection or UTM zone also, in order to assure relative positional accuracy.
- (D3) Reproject adjacent map data into the same geographic projection or UTM zone before joining.
- Check for edgematch problems and edgematch polygons and lines using manual or automated methods. Rebuild topology and attribute data for new map unit containing combined adjacent datasets.

COMMON PROBLEMS WITH GIS DATA
(A) PROBLEM
(B) EFFECT ON GIS OUTPUT
(C) EFFECT ON UTILITY OF GIS APPLICATION
(D) ALTERNATIVES

- (A1) Contents of data-base are unknown
- (B1) Not knowing the contents of the data base slows down the search for the appropriate input needed for an application.
- (C1) If the contents of the data base are unknown then the contents of the outputs derived from the data base have no meaning or reliability.
- (D1) Keep a separate data base for tracking datasets contained in the GIS data base (meta-data base).
- Keep paper copies of the meta-data base in a data dictionary.

- (A2) Input data does not exist

- (B2) Outputs cannot be generated without input data.

- (C2) No applications can be generated without input data.

- (D2) Generate source data for the project if the resources exist.
- Consider alternate appli-cations if appropriate input data cannot be obtained.

- (A3) One or more of the inputs of map data have no geographic control, for example, interpretations of landcover from conventional aerial photography have no control
- (B3) In order to overlay properly, two separate pieces of map data for the same area need to have the same geographic control. Outputs that contain combinations of inputs with different geographic control will not overlay or register properly.
- (C3) Erroneous results will occur when input datasets of no geographic control are combined with inputs with geographic control. Positional accuracy will be severely affected.
- (D3) Develop a separate control set of geographic coord-inates for control points on the input data. Control points can be picked with a GPS. Transform the input data to geographic-ally register with the control set of coordinates, and place information for all inputs into a common geographic projection.

GLOSSARY

ACCURACY - 1. If applied to paper maps or map data bases, degree of conformity with a standard or accepted value. Accuracy relates to the quality of a result and is distinguished from precision. 2. If applied to data collection devices such as digitizers, degree of obtaining the correct value.

ANALYSIS - An operation that examines the data with the intent to extract or create new data that fulfill some required condition or conditions. It includes such GIS functions as topological overlay, buffer generation, and modeling.

ANNOTATION - Descriptive text used to label coverage features. Annotation is not topologically linked with other features. Used for display purposes; it is not used in analysis. Information stored for annotation includes a text string, the location at which can be displayed, and a text symbol (color, font, size, etc.) for displaying the annotation. More than one set of annotation can be created for a coverage.

AREA - A closed feature (polygon) bounded by one or more lines enclosing a homogeneous area and usually represented only in two dimensions. Examples are states, lakes, census tracts, aquifers, and smoke plumes.

ATTRIBUTE - A characteristic of a map feature described by numbers or characters, typically stored in a tabular format, and linked to the features by a user-assigned identifier. For example, attributes of a well, represented by a point, might include depth, pump type, and owner.

AUXILIARY INFORMATION - Supplementary knowledge useful to the conduct of an inventory or the interpretation of the project's results (Lund 1986b)

BASEMAP - A map constructed from original survey(s) of observable phenomena, not interpreted nor analyzed, upon which other information may be placed for purposes of comparison or geographical correlation, or construction of other types of maps (USDA Forest Service 1990a).

BIAS - Generally, an effect which deprives a statistical result of representativeness by systematically distorting it, as distinct from a random error which may distort on any one occasion, but balances out the average (Marriott 1990).

BUFFER - A zone of a given distance around a physical entity, such as a point, line or polygon.

CARTOGRAPHY - The art and science of expressing graphically, by maps and charts, the known physical features of the earth, or of another celestial body; usually includes the works of man and his varied activities (DOD 1981).

CONTROL (MAPPING) - A system of points with established positions and/or elevations which are used as fixed references in positioning and correlating map features. Basic Control implies both horizontal and vertical control determined in the field and permanently marked or monumented, that is required to control subordinate surveys. Geodetic Control takes into account the size and shape of the earth; implies a reference spheroid representing the geoid and horizontal- and vertical-control datums. Ground Control is established by ground surveys, as distinguished from control established by photogrammetric methods. The term usually implies geodetic control or basic control (USDA Forest Service 1990a).

CONTROL POINT - 1) (PHOTOGRAMMETRY) Any station in a horizontal and vertical control system that is identified on a photograph and used for correlating the data shown on that photograph. The term is usually modified to reflect the type or purpose. 2) A point located by ground survey with which a corresponding point on a photograph is matched, as a check, in making mosaics (DOD 1981).

COORDINATE - The position of a point in space with respect to a Cartesian coordinate system (x,y, and/or z values). In GIS, a coordinate often represents locations on the earth's surface relative to other locations.

CORPORATE DATA - Data which in one form or another, are in universal use throughout an organization.

CORPORATE DATA BASE - A collection of data combined into one body for the purpose of sharing, comparing, and aggregating corporation-wide, entered from two or more parallel units within an organization.

CORPORATE GEOGRAPHIC INFORMATION SYSTEM - An information system which uses a spatial data base to provide answers to queries of a geographical nature through a variety of manipulations such as sorting, selective retrieval, calculation, spatial analysis and modeling, consisting of two or more separately entered themes from two or more parallel units within an organization.

DATA - A general term used to denote any or all facts, numbers, letters, and symbols that refer to or describe an object, idea, condition, situation, or other factors. May be line graphics, imagery and/or alphanumerics. It connotes basic elements of information which can be processed, stored, or produced by a computer.

DATA BASE - Usually a computerized file or series of files of information, maps, diagrams, listings, location records, abstracts, or references on a particular subject or subjects organized by data sets and governed by a scheme of organization.

DATA BASE DEVELOPMENT - The design and processes required for constructing spatial and attribute data sets in a manner appropriate for use within a GIS.

DATA DICTIONARY - A coded catalog of all data types or a list of items giving data names and structures. May be on-line (referred to an automated data dictionary), in which case the codes for the data types are carried in a data base. Also referred to as DD/D for data dictionary/directory.

DATA SET - A named collection of logically related items arranges in a prescribed manner.

DEM - DIGITAL ELEVATION MODEL. A data file of a topographic surface arranged as a set of regularly spaced x,y,z coordinates, where z represents surface elevation.

DERIVED MAP - A map of selected features of interest (Aldred 1981).

DESCRIPTIVE DATA - Tabular and/or textual data describing the geographic characteristics of map features.

DIGITAL - Usually referring to data that is in a computer-readable format.

DIGITIZER - 1. A device consisting of a table and a cursor with crosshairs and keys used to record the locations of map features as x,y Cartesian coordinates. 2. Title of a person using the device to automate coverages.

DIGITIZING - The process of using a digitizer to automate the locations of geographic features by converting their position on a map to a series of x,y coordinates stored in computer files.

EDGEMATCHING - An editing procedure for adjusting the locations of connecting arcs and polygons that cross coverage or tile boundaries. Ensures that the features intersect the boundary at a common, coincident point.

GEOCODE - The process of identifying an x,y coordinate location from another geographic location description, such as an address. For example, an address for a student can be matched against a DIME or TIGER street network to locate the student's home.

GEOGRAPHIC DATA - The locations and descriptions of geographic features. The compositeof spatial and descriptive data.

GEOMETRONICS - The art and science of recording, measuring, interpreting, handling and displaying information about the earth and its resources. Combines the fields of cartography, remote sensing, geodesy, and photogrammetry (USDA Forest Service 1990a).

GIS - GEOGRAPHIC INFORMATION SYSTEM. An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. Certain complex spatial operations are possible with a GIS that would be very difficult, time consuming, or otherwise impractical.

GLOBAL POSITIONING SYSTEM - A navigation and positioning system, with which the three dimensional geodetic position and the velocity of a user at a point on or near earth can be determined in real time. The system consists of a constellation of satellites which broadcast on a pair of ultrastable frequencies. The user's receiver tracks the satellites from any location at any time, thus establishing position and velocity (DOD 1981).

GRAPHIC - Any and all products of the cartographic and photogrammetric art. A graphic may be either a map, chart, mosaic, or even a film strip that was produced using cartographic techniques (DOD 1981).

GROUND TRUTH - Data and observations on the earth's surface normally used to quantify simultaneously recorded remote sensing imagery (Slama 1980).

IMAGE - A graphic representation or description of an object that is typically produced by an optical or electronic device. Common examples include remotely sensed data such as satellite data, scanned data, and photographs. An image is stored as a raster data set of binary or integer values representing the intensity of reflected light, heat, or another range of values on the electromagnetic spectrum. Remotely sensed images are digital representations of the earth.

LAND COVER - That which overlays or currently covers the ground, especially vegetation, water bodies, or structures. Barren land is also considered a "land cover" although technically it lacks cover. The term land cover can be thought of as applying to the setting in which action (one or more different land uses) takes place (USDA Forest Service 1989a).

LAND USE - The primary purpose for which an area of land is used

LAYER - A logical set of thematic data described and stored in a map library. Layers organize a map library by subject matter (e.g. soils, roads, and wells) and extend over the entire geographic area defined by the spatial index of the map library.

LINE - A set of ordered coordinates that represents the shape of a geographic feature too narrow to be displayed as an area (e.g. contours, street centerlines, and streams).

MAP - An abstract graphic representation of the earth's surface that displays spatial relationships among the features, generalizes their appearance to simplify them for the purpose of communication, and applies symbols to aid in interpretation. Many maps are constructed as a two-dimensional surface scaled down to a convenient size.

MAP SCALE - A statement of a measure on the map and the equivalent measure on the earth, often expressed as a fraction of distance, such as 1:24,000. This means that one unit of distance on the map represents 24,000 of the same units of distance on the earth.

The smaller the phenomenon to be studied on the ground the more likely a "large scale" will be required to "zoom in" on the situation. Investigating larger phenomena may require "smaller scales" to "zoom out", in order to achieve the proper perspective. Sometimes "large scales" are used to study phenomena over broad areas. In this case, many detailed map segments may need to be developed separately for logistical and technical reasons, then pieced together for the broader expanse of land (this is known as tiling).

MAPPING - The identification of selected features, the determination of their boundaries or locations, and the delineation of those boundaries or locations on a suitable base using pre-defined criteria.

MODEL - A set of rules and procedures for conducting spatial analysis to derive new information that can be analyzed to aid in problem solving and planning. Analytical tools in a geographic information system (GIS) are used for describing the spatial distribution of a natural or social phenomenon. Models can include a combination of logical expressions, analytical procedures, and criteria, which are applied for the purpose of simulating an outcome, predicting an outcome, or characterizing a phenomenon.

MONITORING - The collection of serial data to detect changes or evaluate trends as well as to understand how a system functions (Lund 1986a).

OPERATING SYSTEM - Computer software designed to allow a user to communicate with the computer. The system controls the flow of data, the application of other programs, and the display of information.

PIXEL - The smallest, most elementary areal constituent of an image (also called a resolution cell) (Haddon 1988).

PLATFORM - The vehicle that holds a sensor. It is usually a satellite, but may be a plane or a helicopter. Sensors can be mounted on tripods for certain uses, such as examining electromagnetic radiation from various types of vegetation (DOD 1981).

POINT - A single x,y coordinate that represents a geographic feature too small to be displayed as a line or area.

POLYGON - An areal feature defined by the series of arcs [lines] comprising its boundary. A polygon contains a label point inside its boundary and has attributes that describe the geographic feature it represents.

PROJECTION - A mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface. Some map projections preserve the integrity of shape, others preserve accuracy of area, distance, or direction.

RDBMS - RELATIONAL DATA BASE MANAGEMENT SYSTEM. A data base management system with the ability to access data organized in tabular files that may be related together by a common field. An RDBMS has the capability to combine the data items from different files, thus providing powerful tools for data usage.

RUBBER SHEETING - A procedure to adjust the features of a coverage in a nonuniform manner. Links representing from- and to-locations are used to perform the adjustment.

SCALE - see map scale

SCALE BAR - A map element graphically depicting the map scale.

SCANNING - The process of coordinate data input in raster format with a device called a scanner. Some scanners also use software that converts raster data to vector data.

SOFTWARE - A computer program that provides the instructions necessary for the hardware to operate correctly and to perform the desired functions. Some kinds of software are operating systems, utilities, and applications.

SPATIAL DATA - Information about the location, shape, and relationships among geographic features, usually stored as coordinates and topology.

STANDARD DEVIATION - The positive square root of the variance. Sometimes called RMS for "root mean square". Standard deviation usually refers to variation among observations (Marriott 1990).

TABULAR DATA - Numeric and character data used to provide descriptive information about graphic features.

TEMPORAL RESOLUTION - The time frame over which successive measurements are taken. Temporal resolution is important to consider when we attempt to inventory and monitor dynamic systems. Particularly when it is necessary to integrate data that is collected over significantly different time periods.

THEMATIC DATA - see descriptive data

TOPOGRAPHIC MAP - A map of land-source features, including drainage lines, roads, landmarks, and usually relief or elevation.

TOPOLOGY - The spatial relationships between connecting or adjacent coverage features (e.g.

arcs, nodes, polygons, and points). For example, the topology of an arc includes its from- and to- nodes and its left and right polygons. Topological relationships are built from simple elements into complex elements: points (simplest elements), arcs (sets of points), areas (sets of connected arcs), and routes (sets of sections that are arcs or portions of arcs. Redundant data (coordinates) are eliminated because an arc may represent a linear feature, part of the boundary of an area feature or both. Topology is useful in GIS because many spatial modeling operations do not require coordinates, only topological information. For example, to find an optimal path between two points requires a list of which arcs connect to each other and the cost of traversing along each arc in each direction. Coordinates are only necessary to draw the path after it is calculated.

TRANSFORMATION - The process of converting data from one coordinate system to another through translation, rotation, and scaling.

UPDATE - To address change within a data acquisition (inventory, mapping) cycle. The procedure of modifying a portion of an existing data set through sampling, mechanical, or modeling procedures to reflect its present condition (Lund 1986a).

ZOOM - To display a smaller [portion] of a larger region instead of the present spatial data set extent to show greater or lesser detail.

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